International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 2, Apr 2018, 337-348

FUZZY KANO – VIKOR INTEGRATED APPROACH FOR SUPPLIER SELECTION – A CASE STUDY

SURESH KILAPARTHI[1] & NARAYANARAO SAMBANA[2]

[1]*Assistant Professor, Department of Industrial Engineering, GITAM Institute of Technology, GITAM, Visakhapatnam, Andhra Pradesh, India*

[2]*Professor, Department of Mechanical Engineering, GITAM Institute of Technology, GITAM, Visakhapatnam, Andhra Pradesh, India*

ABSTRACT

In the present days, meeting the customers' expectations is the lifeblood of any manufacturing firm. To produce products as desired by the customers, the firms have to procure right raw material from the right supplier. In fact, supplier identification and selection is one of the key activities performed by purchasing group of a firm to ensure maximum value to the firm. While taking decision on selecting raw material supplier, it is foreseeable to consider various qualitative and quantitative conflicting factors. Because of the lack of precise and exact information about the suppliers against these factors, the supplier selection problem becomes complex. In order to address the complexity involved in the supplier selection problem, a methodology has been proposed in this paper by integrating Fuzzy Kano model analysis and VIKOR (technique for order preference by similarity to ideal solution) technique. To categorize and prioritize the supplier selection attributes Fuzzy Kano model analysis is employed. The VIKOR resolves the uncertainty while selecting the best supplier among the suppliers of a firm. The proposed methodology resolves the ambiguity during the identification of supplier selected attributes as well as a selection of suppliers. A case study has been presented in this paper to demonstrate the proposed methodology.

***KEYWORDS:** Supplier Selection, Supplier Selection Attributes, Fuzzy Kano Technique & VIKOR*

Received: Jan 15, 2018**; Accepted:** Feb 06, 2018**; Published:** Mar 02, 2018**; Paper Id.:** IJMPERDAPR201837

I. INTRODUCTION

In order to sustain in the present market scenario, manufacturing firms should focus primarily on producing products to delight the customers in terms of quality. They need to adopt a customer satisfaction strategy to face the challenges in the market. To produce qualitative products, they need to purchase appropriate raw material from a reliable supplier. Manufacturing firms should choose the right suppliers for producing quality products, thereby achieving end customer satisfaction. As the manufacturers have to purchase raw material from suppliers, they are the customers (buyers) and hence their satisfaction is the most considerable aspect for the logistic companies. To maintain a competitive edge in the current market scenario, logistic companies should focus on attaining customer satisfaction, otherwise manufacturing firms will look for other alternative raw material supplier with a view to satisfying their own customers. The incorrect decision on choosing a raw material supplier affects the entire supply chain in addition to the specific buyer. It leads to the scope of purchasing risk, failure of long-term relationship between buyers and suppliers and decreasing the overall value to the firm.

To strengthen the supplier selection process, manufacturing firms are using supplier selection criteria for establishing effective relationship with suppliers (Vonderembse and Tracey, 1999). Dickson (1966) mentioned twenty three criteria for his extensive study. He noticed that cost, quality and delivery performance were the three most important criteria in the supplier selection process. Braglia and Petroni (2000) proposed a number of supplier selection attributes include managerial capability, financial stability, experience, reputation, geographical location, reliability, customer service and price. Ho et al. (2010) reviewed several articles about supplier selection from 2000 to 2008 and they concluded that the most popular criterion considered by the decision makers is quality, followed by delivery, price, manufacturing capability, service etc. It is observed from the literature survey, most of the researchers primarily considered price, delivery and quality as the attributes for supplier selection.

As multiple criteria in terms of both qualitative as well as quantitative influences on selecting a supplier for a manufacturing firm, the supplier selection problem can be considered as a multi-criteria decision making problem. Most of the researchers have been developing numerous methodologies using simple weighting techniques to an advanced level of mathematical techniques. A wide variety of techniques such as linear weighting model, categorical model, weighted point model, total cost of ownership model, artificial neural network model etc. employed for solving supplier selection problems with only quantitative information. A little amount of work has been done in the area of application of multi-criteria decision making methods for solving supplier selection problem (Chatterjee et al., 2011). Pal et al., (2013) emphasized the need of attention on developing solution methodologies for supplier selection problem by harmonizing the combination of qualitative and quantitative criteria. At present researchers are focusing on developing hybrid methodologies or integrated methodologies to provide effective solutions for supplier selection problem (Prasad et al., 2016). Wu (2009) proposed a hybrid decision model using data envelopment analysis, decision trees and neural networks to estimate the performance of suppliers. Elanchezhian et al., (2010) made an attempt to select the best vendor by using the analytic network process and TOPSIS. Haldar et al.(2012) established a hybrid MCDM model by using AHP-QFD methodology for resilient supplier selection. Kassaee et al. (2013) proposed an integrated hybrid MCDM model using fuzzy analytic network process and fuzzy TOPSIS to determine the weights of sub-criteria and attain the rank of the vendors. Zahar et al. (2014) proposed a fuzzy MCDM approach by using fuzzy TOPSIS with a view to rank the artificial hip prosthesis suppliers. Siadat and Maleki (2015) employed TOPSIS method under green supply chain criteria to rank the suppliers. It is observed in the recent literature, many researchers have used TOPSIS and VIKOR methods for developing decision making models for obtaining a solution for supplier selection problem. The application of these two methods can help for the best supplier selection on the basis of different criteria while considering their relative importance (Rajiv and Darshana, 2014). As VIKOR has much advantage over TOPSIS under group decision making environment (Liu, 2016), in this paper an attempt has been made to apply VIKOR technique developing methodology with a view to solving supplier selection problem. In order to categorize the attributes for supplier selection and to obtain their weightings, the fuzzy Kano technique has been employed in the proposed methodology. The overview of Kano model, fuzzy logic and VIKOR technique are discussed briefly in the following paragraphs.

1.1. Kano Technique

Prof. Noriaki Kano and his colleagues proposed Kano technique in the year 1980. The purpose of the technique is to categorize the attributes of a product or service on the basis of how they are able to satisfy the needs of the customers. It is proven that the two-dimensional quality model addressed by Kano is an effective instrument for analyzing customer needs

(Lee and Huang, 2009). Usually, customer attributes can be classified into the following five categories (Ghorbani et al., 2013) using Kano technique.

- **Must-be Attributes (M):** These are attributes that often are unnoticed by customers and sufficiency of them will not result more satisfaction but insufficiency of these elements will result dissatisfaction.
- **One-Dimensional Attributes (O):** These are attributes that sufficiency of them will result satisfaction and insufficiency of them will result dissatisfaction. These attributes are also termed 'more is better' or 'faster is better'.
- **Attractive Attributes (A):** These are attributes that sufficiency of them will cause customers to feel excitement and their absence will not dissatisfy customers.
- **Indifferent Attributes (I):** These are attributes that sufficiency or insufficiency of them will not affect customer satisfaction.
- **Reverse Attributes(R):** These are attributes that if they are provided, customer will be dissatisfied and vice versa.

Dr. Kano proposed Kano questionnaire consists of functional and dysfunctional questions as an instrument for conducting Kano model analysis with a view to categorizing customer attributes. The questionnaire examines each customer need with a pair of questions in functional and dysfunctional forms. There are five possible answers for each pair of questions such as: like, must-be, one-dimensional, neutral, live with and dislike. On the basis of customer responses to both questions, the customer need is classified as one of the five Kano categories for that customer by checking the Kano evaluation table (Berger et al., 1993). Berger et al.,(1993) proposed customer satisfaction index (CS), which is calculated by dividing the sum of frequencies of attractive (f_A) and one-dimensional (f_O) attributes with the sum of the frequencies of attractive, one-dimensional, must be (f_M) and indifferent attributes (f_I). The value of customer satisfaction index lies between 0 and 1. The values of CS close to 1 indicate greater satisfaction while the values close to 0 indicate lower satisfaction.

1.2. Fuzzy Logic Technique

Prof. L. A. Zadeh of the University of California at Berkeley invented fuzzy logic technique in 1965 (Lee and Huang, 2009). This technique is based on the intuitive reasoning by taking into account the human subjectivity and imprecision. The fuzzy logic theory is based on fuzzy sets which are a natural extension of the classical set theory. In classical set theory, an individual object is either a member or a non-member of a set. But in real practice, because of insufficient knowledge or imprecise data, it is not always clear whether an object belongs to a set or not. Fuzzy logic technique allows an object belonging to multiple exclusive sets in the resulting frame work.

1.3. VIKOR Technique

The VIKOR (the Serbian name is 'VIšekriterijumsko KOmpromisno Rangiranje' which means multi-criteria optimization and compromise solution) method was mainly established by Zeleny and later advocated by Opricovic and Tzeng (Adhikary et al., 2015). This technique helps to provide solution for multi-criteria decision making problems with conflicting and non-commensurable criteria (Opricovic and Tzeng, 2007), assuming that a compromise can be acceptable for conflict resolution, when the decision maker wants a solution that is the closest to the ideal solution and farthest from the negative-ideal solution, and the alternatives can be evaluated with respect to all the established criteria. This method

helps to solve multi-criteria decision making problems with conflicting and non-commensurable criteria (Opricovic and Tzeng, 2007), assuming that a compromise can be acceptable for conflict resolution, when the decision maker wants a solution that is the closest to the ideal solution and farthest from the negative-ideal solution, and the alternatives can be evaluated with respect to all the established criteria. The primary focus of this technique is to rank and select the best alternative from a set of alternatives with conflicting criteria, and on proposing the compromise solution. In fact, the compromise solution is a feasible solution, which is the closest to the ideal solution, and a compromise means an agreement established by mutual concessions made between the alternatives (Rao, 2007). In VIKOR method, the best alternative is preferred by maximizing utility group and minimizing regret group. This method calculates ratio of positive and negative ideal solution. In addition to ranking, the VIKOR method proposes a compromise solution with an advantage rate (Tzeng and Huang, 2011). Therefore, in the present work an integrated approach has been developed by using fuzzy based - Kano and VIKOR techniques with a view to solving supplier selection problem.

II. METHODOLOGY

The outline of the proposed methodology is shown in figure 1. In this methodology, the priority structure of supplier selection attributes is obtained by using fuzzy based Kano technique. The weightages of the supplier selection attributes obtained through the fuzzy Kano technique provide a scope to deploy customer desires, which will be reflected in determining the VIKOR index for each supplier. On the basis of VIKOR indices it is easier for a decision maker to identify the best supplier.

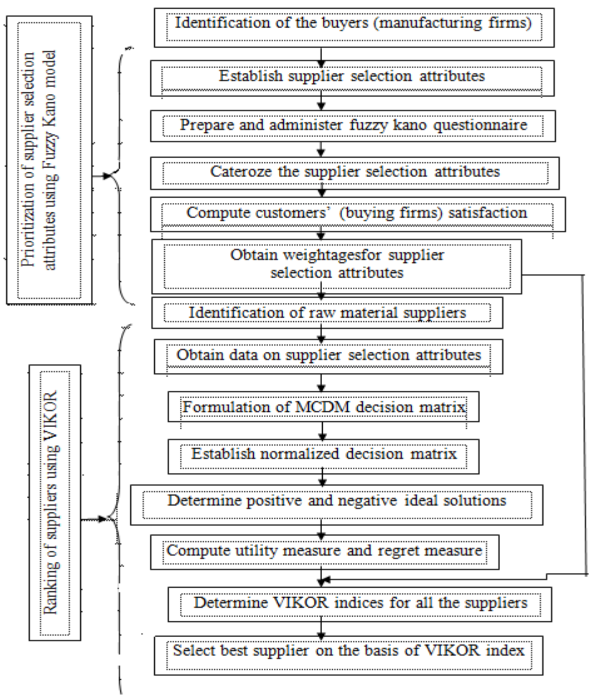

Figure 1: Outline of the Proposed Methodology

The step by step methodology is discussed below.

Step 1: Identify the Buyers (Manufacturing Firms)

In order to obtain the responses on raw material suppliers, identify the raw material buying firms who are procuring same raw material from different suppliers after supplier qualification screening process.

Step 2: Establish Supplier Selection Attributes

To strengthen the supplier selection process, it is essential to establish appropriate supplier selection attributes. The supplier selection attributes have to be finalized with the involvement of purchase department personnel, stores manager, and field manager of the buying firms as they are the decision makers on purchasing raw material.

Step 3: Prepare and Administer Fuzzy Kano Questionnaire

After establishing the attributes for supplier selection, prepare fuzzy Kano questionnaire. The questionnaire contains questions in both functional and dysfunctional forms with a scope for buying firms to give more than single response. The questionnaire has to be distributed to buying firms with a view to obtaining the responses on supplier selection attributes.

Step 4: Categorize the Attributes Using Kano Technique

After establishing the attributes for supplier selection, prepare fuzzy Kano questionnaire. The questionnaire contains questions in both functional and dysfunctional form with a scope for buying firms to give more than single response.

Step 5: Determine Customer (Buying Firm) Satisfaction Indices for all the Attributes

The customer satisfaction index (CS), which is calculated by dividing the sum of frequencies of attractive (f_A) and one-dimensional (f_O) attributes with the sum of the frequencies of attractive, one-dimensional, must be (f_M) and indifferent attributes (f_I). The value of customer satisfaction index lies between 0 and 1. The values of CS close to 1 indicate greater satisfaction while the values close to 0 indicate lower satisfaction.

Step 6: Obtain Priority Structure (Weight Ages) for Supplier Selection Attributes

The normalized values of customer satisfaction indices give the weight ages for the supplier selection attributes.

Step 7: Identification of Supplier Selection Attributes

The attributes for supplier selection are usually depends on the type of firm, product, purchasing capability etc. The top level executives are generally involved in the identification of supplier selection attributes.

Step 8: Developing and Administering Kano Questionnaire

Kano questionnaire has to be prepared by incorporating the functional and dysfunctional forms of questions on supplier selection attributes. To obtain the response data on supplier selection attributes, the questionnaires are distributed to purchasing personnel of manufacturing firms which are producing similar products.

Step 9: Determination Of The Weight Ages For The Supplier Selection Attributes

After determining the customer satisfaction indices (CS) for all the attributes and then by normalizing those values gives the weightages for the supplier selection attributes.

Step 10: Formulation of MCDM Decision Matrix

The MCDM decision matrix has to be formed as shown below.

	Cx_1	Cx_2	Cx_3	Cx_n
A_1	x_{11}	x_{12}	x_{13}	x_{1n}
A_2	x_{21}	x_{22}	x_{23}	x_{2n}
A_3	x_{31}	x_{32}	x_{33}	x_{3n}
A_m	x_{m1}	x_{m2}	x_{m3}	x_{mn}

Where A_i = the i^{th} alternative (i =1, 2,………., m)

Cx_j = the j^{th} criterion (j =1, 2,........., n)

x_{ij} = individual performance of an alternative.

Step 11: Representation of Normalized Decision Matrix

The normalized decision matrix can be expressed as follows:

$$F = \left[f_{ij} \right]_{m \times n}$$

Where, $f_{ij} = \dfrac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$, i =1,2,……, m; j =1,2,……, n; and x_{ij} is the performance of alternative A_j with respect to the j^{th} criterion.

Step 12: Determine Positive-Ideal Solution and Negative-Ideal Solution

The positive ideal solution A^* and the negative ideal solution A^- are determined as follows:

$$A^* = \left\{ \left(\max f_{ij} \mid j \in J \right) \text{or} \left(\min f_{ij} \mid j \in J \right) \middle| i = 1, 2, \ldots.., m \right\} = \left\{ f_1^*, f_1^*, \ldots. f_j^*, \ldots., f_n^* \right\}$$

$$A^- = \left\{ \left(\min f_{ij} \mid j \in J \right) \text{or} \left(\max f_{ij} \mid j \in J \right) \middle| i = 1, 2, \ldots.., m \right\} = \left\{ f_1^-, f_1^-, \ldots. f_j^-, \ldots., f_n^- \right\}$$

Step 13: Calculate Utility Measure and Regret Measure

The Utility measure (S_i) and Regret measure (R_i) for each alternative are computed using the following expressions

$$S_i = \sum_{j=1}^{n} w_j \times \left[\frac{\left(f_j^* - f_{ij} \right)}{\left(f_j^* - f_j^- \right)} \right] \text{ and } R_i = \max_j \left[w_j \times \frac{\left(f_j^* - f_{ij} \right)}{\left(f_j^* - f_j^- \right)} \right]; \text{ where } w_j = \text{weight of the } j^{\text{th}} \text{ criterion.}$$

Step 14: Compute VIKOR Indices

The VIKOR index is calculated by using the following expression.

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1-v)\left[\frac{R_i - R^*}{R^- - R^*}\right]$$

Where, Q_i represents the i^{th} alternative VIKOR value, i=1, 2,……., m; $S^* = \min_i(S_i)$, $S^- = \max_i(S_i)$,

$R^* = \min_i(R_i)$, $R^- = \max_i(R_i)$ and v is the weight of the maximum group utility and its value is usually set to 0.5 (Opricovic, 1994).

Step 15: Rank the Order of Preference

The alternative which is having smallest VIKOR index value is the best solution.

III. CASE STUDY

In order to demonstrate the proposed methodology, a case study has been carried in a forging firm located in Visakhapatnam, Andhra Pradesh, India. The forging firm procures raw materials such as En8d, AISI, and En9for producing various products, namely flanges, bolts, nuts, clutches, hubs and gears. At present the forging firm is exercising bidding technique for the selection of supplier to procure the necessary raw materials. The parameters such as quality, lead time are not considered by the firm. But the firm has to ensure that their products should meet the quality and specification standards for sustainability of the company in the competitive market scenario. In order to achieve this, the present study has been carried with a view to select the best supplier for the forging firm to procure raw materials. To identify the supplier selection attributes and to obtain their priority structure, nine prominent forging firms located in the coastal districts of Andhra Pradesh are considered. They are producing similar kinds of products. In order to enlist the attributes for selecting raw material suppliers, group discussions conducted among the purchase managers, store managers, and field managers, etc. The outcome of the discussion provided the seven supplier selection attributes i.e., quality, price, delivery, service, quality assurance, management capability and organization profile. After identifying the supplier selection attributes, fuzzy questionnaire has been prepared (Suresh and Narayana Rao, 2017). The questionnaire consists of 14 functional and 14 dysfunctional questions on seven attributes. The questionnaires are distributed to the purchase personnel (Decision makers on purchase of raw materials) of nine firms. The respondents are asked to give your response on each question with number of preferences ranging from 0 to 1 instead of a single number value. After obtaining the response data from the nine decision makers, the Kano categorization of the attributes has been carried and is shown in Table 1.

Table 1: Kano Categorization of Supplier Selection Attributes

Attributes	Items Dealing with Customers (Buying Firms) Requirements	A	O	M	I	R	Q	Total	Kano Category
Delivery	Compliance with due date	1	4	3	0	1	0	9	O
Quality	Rejection in incoming quality control	1	8	0	5	0	0	14	O
	Rejection from customer	2	7	1	0	0	1	11	O
Price	Raw material price	0	7	0	1	1	0	9	O
Material handling	Material handling cost	1	5	2	3	0	0	11	O
	Storage cost	2	3	2	2	0	0	9	O
Customer service	Warranty period	0	6	2	1	0	0	9	O
	Response to rejection	2	4	2	1	0	0	9	O
Technical capability	Quality staff	2	1	0	7	0	0	10	I
	Product development	2	7	0	0	0	0	9	O
	Process improvement	1	8	0	0	0	0	9	O

	Quality planning	1	7	0	1	0	0	9	O
	Quality assurance production	2	5	1	0	0	0	8	O
Procedural compliance	Documentation and self audit	2	1	0	7	0	0	10	I

From the Table 1, it is observed that the attributes delivery, quality, price, customer service, technical capability and procedural compliance come under the category of one dimensional attributes. This means that the manufacturing firms need these attributes in sufficient level in the raw material suppliers, otherwise they will get dissatisfaction. The firms considered the procedural compliance under indifferent attributes category. The customer satisfaction indices for all the attributes are computed as discussed in the step 5 of the proposed methodology. The weightages for the attributes are computed by normalizing the values of customer satisfaction indices. The customer satisfaction indices and the weightages for the supplier selection attributes are summarized in Table 2.

Table 2: Customer Satisfaction Indices and Weightages for the Supplier Selection Attributes

Supplier Selection Attributes	Delivery	Quality	Price	Material Handling	Customer Service	Technical Capability	Procedural Compliance
Customer satisfaction index	0.625	0.771	0.875	0.551	0.667	0.813	0.300
Weightage (w_j)	0.136	0.168	0.190	0.120	0.145	0.177	0.065

From the table 2, it is revealed that the forging firms are giving priority to the price, technical capability, quality, delivery and customer service in order. They have given less preference to material handling and procedural compliance attributes. At present the case company (forging firm in which the study is carried) has six potential suppliers for procuring necessary raw materials. In this paper the six potential suppliers are coded as S_A, S_B, S_C, S_D, S_E and S_F with a view to maintaining anonymity. In order to obtain the responses regarding supplier selection attributes, supplier performance assessment questionnaires are administered to the purchasing personnel of the company. The response data obtained through questionnaire survey are shown in Table 3.

Table 3: The Response Data on Supplier Selection Attributes

Supplier	Supplier Selection Attributes						
	Delivery	Quality	Price	Material Handling	Customer Service	Technical Capability	Procedural Compliance
S_A	0.23	0.73	0.31	0.48	0.00	0.98	0.45
S_B	0.73	0.98	0.64	0.23	0.98	0.00	0.98
S_C	0.98	0.23	0.64	0.48	0.31	0.00	0.44
S_D	0.73	0.73	0.31	0.98	0.00	0.98	0.98
S_E	0.00	0.23	0.31	0.98	0.31	0.64	0.00
S_F	0.00	0.73	0.98	0.00	0.64	0.98	0.55

The normalized decision matrix is developed as discussed in step 11 of the section 2. The normalized decision matrix is obtained as given below.

$$\begin{bmatrix} 0.1595 & 0.4471 & 0.2155 & 0.3076 & 0.0000 & 0.5402 & 0.2780 \\ 0.5062 & 0.6003 & 0.4450 & 0.1474 & 0.7840 & 0.0000 & 0.6055 \\ 0.6796 & 0.1408 & 0.4450 & 0.3076 & 0.2480 & 0.0000 & 0.2718 \\ 0.5062 & 0.4471 & 0.2155 & 0.6280 & 0.0000 & 0.5402 & 0.6055 \\ 0.0000 & 0.1408 & 0.2155 & 0.6280 & 0.2480 & 0.3528 & 0.0000 \\ 0.0000 & 0.4471 & 0.6814 & 0.0000 & 0.5120 & 0.5402 & 0.3398 \end{bmatrix} \quad (1)$$

The positive ideal solution (PIS) and negative ideal solutions (NIS) are determined by considering the data under two approaches such as the larger is better and smaller is better. For each selection attribute the PIS $\left(f_j^*\right)$ and NIS $\left(f_j^-\right)$ are expressed as follows.

For Delivery (Smaller is Better): $f_j^* = 0.000$ and $f_j^- = 0.670$

For Quality (Larger is better): $f_j^* = 0.600$ and $f_j^- = 0.140$

For Price (Smaller is Better): $f_j^* = 0.210$ and $f_j^- = 0.680$

For Material handling (Smaller is Better): $f_j^* = 0.000$ and $f_j^- = 0.620$

For Customer service (Larger is better): $f_j^* = 0.780$ and $f_j^- = 0.000$

For Technical capability (Larger is better): $f_j^* = 0.540$ and $f_j^- = 0.000$

For Procedural compliance (Larger is better): $f_j^* = 0.600$ and $f_j^- = 0.000$

The utility measure $\left(S_i\right)$ and regret measure $\left(R_i\right)$ for all the supplier selection attributes have to be determined. As discussed in step 13 of the section 2, the values of $\left(S_i\right)$ and $\left(R_i\right)$ for delivery are computed as follows.

$$S_{\mathrm{A1}} = 0.136 \times \frac{0.000 - 0.1595}{0.000 - 0.670} = 0.0323$$

$$S_{\mathrm{B1}} = 0.136 \times \frac{0.000 - 0.5062}{0.000 - 0.670} = 0.1027$$

$$S_{\mathrm{C1}} = 0.136 \times \frac{0.000 - 0.6796}{0.000 - 0.670} = 0.1379$$

$$S_{\mathrm{D1}} = 0.136 \times \frac{0.000 - 0.5062}{0.000 - 0.670} = 0.1027$$

$$S_{\mathrm{E1}} = 0.136 \times \frac{0.000 - 0.000}{0.000 - 0.670} = 0.000$$

$$S_{\mathrm{F1}} = 0.136 \times \frac{0.000 - 0.000}{0.000 - 0.670} = 0.000$$

The utility measures for all other attributes with respect to all the suppliers are computed in the same manner and utility matrix is prepared and is presented below.

$$S_{ij} = \begin{bmatrix} 0.0323 & 0.0558 & 0.0022 & 0.0595 & 0.1450 & 0.0000 & 0.0348 \\ 0.1027 & 0.0000 & 0.0950 & 0.0285 & 0.0000 & 0.1770 & 0.0000 \\ 0.1379 & 0.1676 & 0.0950 & 0.0595 & 0.0988 & 0.1770 & 0.0355 \\ 0.1027 & 0.0558 & 0.0022 & 0.1215 & 0.1450 & 0.0000 & 0.0000 \\ 0.0000 & 0.1676 & 0.0022 & 0.1215 & 0.0988 & 0.0613 & 0.0650 \\ 0.0000 & 0.0558 & 0.1906 & 0.0000 & 0.0498 & 0.0000 & 0.0281 \end{bmatrix}$$

The utility measure $\left(S_i\right)$ and regret measure $\left(R_i\right)$ for all the suppliers are computed as discussed in the step 13 of section 2. The Table 4 shows the values of utility measure and regret measure for all the six suppliers.

Table 4 Utility Measure and Regret Measure of the Suppliers

Supplier	Utility Measure $\left(S_i\right)$	Regret Measure $\left(R_i\right)$
S_A	0.3298	0.1450
S_B	0.4033	0.1770
S_C	0.7716	0.1770
S_D	0.4273	0.1450
S_E	0.5167	0.1676
S_F	0.3244	0.1906

The VIKOR index for each supplier is computed as discussed in step 14 of the methodology discussed in the previous section.

For supplier S_A:

$$Q_A = 0.5\left[\frac{0.3298-0.3244}{0.7716-0.3244}\right]+\left(1-0.5\right)\left[\frac{0.145-0.145}{0.1906-0.145}\right]=0.006$$

For supplier S_B:

$$Q_2 = 0.5\left[\frac{0.4033-0.3244}{0.7716-0.3244}\right]+\left(1-0.5\right)\left[\frac{0.177-0.145}{0.1906-0.145}\right]=0.439$$

For supplier S_C:

$$Q_3 = 0.5\left[\frac{0.7716-0.3244}{0.7716-0.3244}\right]+\left(1-0.5\right)\left[\frac{0.1770-0.145}{0.1906-0.145}\right]=0.850$$

For supplier S_D:

$$Q_4 = 0.5\left[\frac{0.4273-0.3244}{0.7716-0.3244}\right]+\left(1-0.5\right)\left[\frac{0.145-0.145}{0.1906-0.145}\right]=0.115$$

For supplier S_E:

$$Q_5 = 0.5\left[\frac{0.5167-0.3244}{0.7716-0.3244}\right]+\left(1-0.5\right)\left[\frac{0.1676-0.145}{0.1906-0.145}\right]=0.463$$

For supplier S_F:

$$Q_6 = 0.5\left[\frac{0.3244-0.3244}{0.7716-0.3244}\right]+(1-0.5)\left[\frac{0.1906-0.145}{0.1906-0.145}\right]=0.500$$

The VIKOR indices for all the five suppliers are summarized in table 5.

Table 5 VIKOR Indices for all the Suppliers

Supplier	S_A	S_B	S_C	S_D	S_E	S_F
VIKOR Index	0.006	0.439	0.850	0.115	0.463	0.500

It is observed from the table 5, the supplier S_A has a lower value of VIKOR index. According to VIKOR method the alternative with the lower value of VIKOR index is the best alternative among the number of alternatives under consideration. Therefore, the supplier S_A is the best supplier.

IV. CONCLUSIONS

The integrated methodology proposed in this paper is developed to address supplier selection problem in a manufacturing firm. The methodology is established by integrating fuzzy based Kano and VIKOR techniques. The fuzzy Kano technique used resolves the ambiguity, while categorizing the preferences of manufacturing firms on supplier selection attributes. It also provides the weightages of the supplier selection attributes by reflecting the preferences of manufacturing firms. Since the supplier selection is a multi-criteria group decision problem, VIKOR technique is employed in the proposed methodology. Under the circumstances where qualitative and quantitative factors are involved in the multi-criteria decision making in supplier selection, the proposed methodological approach provides a solution path for the decision makers of any manufacturing firm.

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